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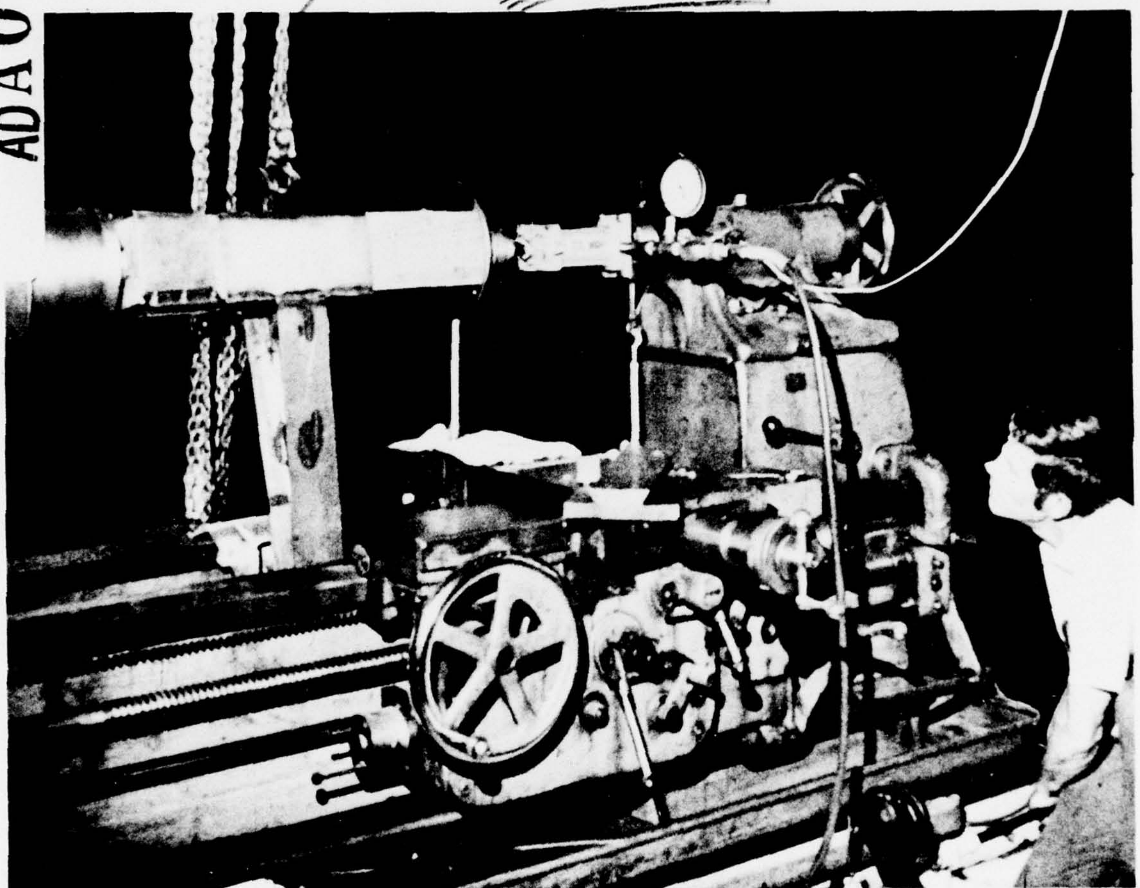

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ABSTRACT

In seeking the cause of spin-out, the torque needed to turn basswood blocks into 1/4-in.-thick rotary veneer was measured for different lathe settings and block temperatures. Increasing the wood temperature reduced the force needed for cutting and also reduced torque that could be accepted by wood blocks before failing by spin-out. Maximum torque developed in wood blocks at room temperature depended on the size, number, and shape of spurs on the 4-in.-diameter chucks. Friction drive on the block surface is suggested as an auxiliary source of torque for turning wood blocks into veneer.

SPIN-OUT OF VENEER BLOCKS DURING ROTARY CUTTING OF VENEER

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INTRODUCTION

Veneer is the most valuable product recovered from a block of wood. As the price of stumpage has risen, the maximum recovery of veneer has become even more important.

At the same time, the diameter of the average block being cut into veneer has become smaller. Thus, with a constant core diameter, a larger percent of the raw material input is left as core.

In general, a major goal of the veneer industry is to cut to as small a core diameter as possible. For 8-foot-long blocks cut on dual spindle lathes, the minimum size of the inner chucks is about 4 inches (in.). Even with the best practice a certain percentage of the blocks will spin-out or break out of the lathe before cutting to the desired core.

Estimates from industry indicate that about 25 percent of woods-run logs are not peelable due to soft centers and end splits. This correlates to the two rather distinctly different ways a block fails to peel to the desired core diameter--spin-out and split-out.

Spin-out of veneer blocks occurs when the torque required for cutting exceeds the torque that can be delivered by the chucks that grip and turn the block ends. When the chucks turn in the block ends, veneer cutting stops. Spin-out occurs most often with low-density woods like aspen, basswood, and white fir. Excessive heating that softens the block ends has reportedly aggravated the problem with fairly dense species like southern pine.

Split-out is a catastrophic event that occurs when the combination of cutting forces and the driving force from the chucks exceeds the ability of the bolt to resist splitting. Split-out is most likely to occur with blocks of old-growth wood that have large diametric splits or ring shake. Douglas-fir and the oaks are species that typically show split-out. Cutting usually proceeds satisfactorily until the split or the ring shake in the block is exposed by peeling. Then if a large chunk breaks from the block, peeling will stop.

In general, the larger the block diameter, the greater the torque required for a given cutting force:

$$T = FL$$

where T is torque in pound-foot (lb-ft) or Newton meter (N-m), F is the cutting force, and L is the distance between the line of action and the axis about which the wood block turns.

For example, assume a constant cutting force of 100 pounds per inch (lb/in.) of wood or 10,000 lb for a block 100 in. long. If the block were 24 in. in diameter, the lever arm would be l ft and it would require about 10,000 lb-ft of torque. At a

[1]Maintained at Madison, Wisconsin, in cooperation with the University of Wisconsin.

diameter of 12 in. the lever arm would be 6 in. and the torque would be 5,000 lb-ft. At a core diameter of 6 in. the torque would be 2,500 lb-ft.

The use of retractable chucks is based on less torque being required to cut veneer at smaller block diameters.

Theoretically, spin-out should occur as soon as cutting starts or else not happen. However, from observations in plants, spin-out also occurs part way through the cutting. This could happen when the large chucks are retracted, if the chucks loosen in the block ends, or if the cutting force builds up faster than the lever arm is reduced by cutting to a smaller diameter.

Power is the rate of doing work and so is directly related to cutting force and speed of cut:

$$P = FV$$

where P is power, F is cutting force, and V is cutting speed. Much of the literature on veneer cutting gives data in terms of kilowatts (kw) of power to turn the lathe. Since it includes speed and losses in the machinery, power data may not be as precise as data that give the actual cutting force.

Besides block diameter, torque to turn blocks is also related to length of the block, wood density, veneer thickness, wood temperature, type of pressure bar, setting of the knife, setting of the pressure bar, and cutting speed.

This study is aimed primarily at obtaining a better understanding of spin-out. However, observations were also made of the tendency of different chucks to split the blocks.

This study was conducted in three stages: I, to establish how the torque required to turn a block varies with the lathe setup and the block temperature; II, to determine how chuck design and wood temperature affect the torque a block end will accept before failing by spin-out; and III, to examine the possibility of auxiliary torque input to the block by friction drive on the block surface.

The experiments were exploratory in nature, using only high-grade logs and few replicates. The intent was to obtain a better understanding of forces involved in cutting and the relation between chuck design and transfer of torque to the block.

The last two sections of this report give a synopsis of the overall results and illustrate one way of using them.

STAGE I.--CUTTING FORCE, TORQUE, AND POWER TO TURN WOOD BLOCKS INTO VENEER

Background

Wood Density

Kollmann (6)[2] found that cutting 1-millimeter (mm) thick beech required more than twice as much power as 1-mm-thick poplar, a less dense wood. Similiarly, Peters (13) reported that slicing 1/2-in.-thick red oak required about 330 lb/in. of wood while 1/2-in.-thick yellow-poplar, a less dense wood, required about 250 lb/in. of wood.

Veneer Thickness

Power required to cut beech 1/2, 1, and 1-1/2 mm thick was 2, 4, and 6 kw respectively, according to Kollmann (6). Peters (13) found cutting forces increased approximately 50 percent (pct) when cutting 1-in. rather than 1/2-in.-thick slices of wood at 500 ft/min. This was true for southern pine, red oak, and yellow-poplar.

Wood Temperature

Jain (5) and Kollmann (6) did not find a consistent relationship between wood temperature and the power required to cut veneer. Our study with southern pine (8) indicates that, with the same lathe settings, heated wood exerts less force on the pressure bar. This should mean less friction and so less torque to turn the blocks.

Peters (11) found that, with identical slicer settings, the maximum cutting force when slicing 1-in.-thick Douglas-fir at 200° F was about half the force required at 70° F. This cutting was at 5 ft/min. Fraser (4) reported spin-out at an industrial plant was reduced from 7 to about 3 pct by using a longer time to steam blocks.

Fixed Bar Versus Roller Bar

Less power was required to peel 1/16-in. veneer from red pine blocks when using a roller bar than when using a fixed bar, according to Feihl (3). The 4-ft.-long blocks at room temperature were cut at 20 revolutions per minute. The difference in power consumption was greater when peeling at a 14-in. diameter than when peel-

[2]Numbers in parentheses refer to literature cited at the end of this report.

ing at a 6-in. diameter. Peters (12) found that 1-in.-thick slices of red oak and Douglas-fir cut at 5 ft/min. required slightly less cutting force when using a driven roller bar than when using a fixed bar. With aspen Peters found the cutting forces were nearly equal when using these two types of bars.

Knife Angle

Burrell (2) quotes Lloyd, a manufacturer of lathe drives, as stating "power to turn spindles can be greatly increased if the incorrect knife angle is used." No specific data are given. Jain (5) reported power required to cut veneer from a variety of species using different knife angles. The results were somewhat variable but in general power was at a minimum when using a knife angle of about 91° (1° clearance angle).

Setting of Pressure Bar

Lloyd also stated (2) "as much as 50 percent additional power is required if extremely high pressure is used in the lathe." We (9) found the horizontal load on the pressure bar increased directly with decreasing gap between the pressure bar and knife. This was true when cutting 0.094-and 0.364-in.-thick veneer from yellow-poplar and southern pine. Similarly, Peters (11) showed cutting forces increased directly with increasing compression and restraint by the pressure bar. The increase in cutting force was as much as 2 to 1 with the different settings used. Both the lead of the bar ahead of the knife and the gap between the knife and the pressure bar are important.

Cutting Velocity

Kollmann (6) found the power for peeling veneer increased linearly with cutting speed. This means that for a given diameter, torque did not change regardless of cutting speed. In contrast, Peters (13) found the cutting force increased as the velocity increased from 5 to 500 ft/min. When cutting 1/2-in.-thick red oak, southern pine, and yellow-poplar, the force increased about 25, 80, and 40 pct respectively. The increased cutting force with increased speed may be related to water being expelled from the wood bolts. The greater the cutting speed, the stiffer the wood may be due to trapped water.

Experimental Procedure, I

This first part of the study was to establish how the torque required to turn a block varies with the lathe setup and the block temperature.

We decided to obtain data on the cutting force and torque needed to cut 1/4-in.-thick basswood as related to knife angle, pressure bar lead, pressure bar gap, and wood temperature. These variables were selected as those most readily controlled by the operator. Basswood was used because spin-out is more of a problem with low-density wood. The literature indicates cutting force increases with increasing veneer thickness. Veneer was cut here to 1/4 in. because this is generally the maximum thickness of commercial veneer. The knife angles and pressure bar settings are within the range commonly used in commercial practice. The temperature series includes higher temperature than would normally be used with basswood.

Two logs of basswood were rounded on a lathe to a diameter of 12 in. The rounded bolts were crosscut into successive 6-in.-long blocks. One 6-in. block from each log was cut on a modified engine lathe with settings of one of the test conditions. All blocks were cut into veneer 0.252-in. thick at seven revolutions per minute. The fixture holding the knife and pressure bar was mounted on a load cell. Vertical loads or cutting forces were measured continuously during cutting. The vertical load and block radius was used to compute the maximum torque that occurred during cutting of clear wood.

Results, I

The lathe settings and forces observed in cutting are shown in table 1, and maximum torque needed to cut clear wood from blocks 12 in. in diameter is plotted in figures 1 through 5. These bar graphs show the average and range observed for the two logs run at each condition. The value for the 90° knife angle, 0.030-in. lead, and 90 pct gap in figures 1, 3, and 5 are the average of three runs. A part of a strip chart showing

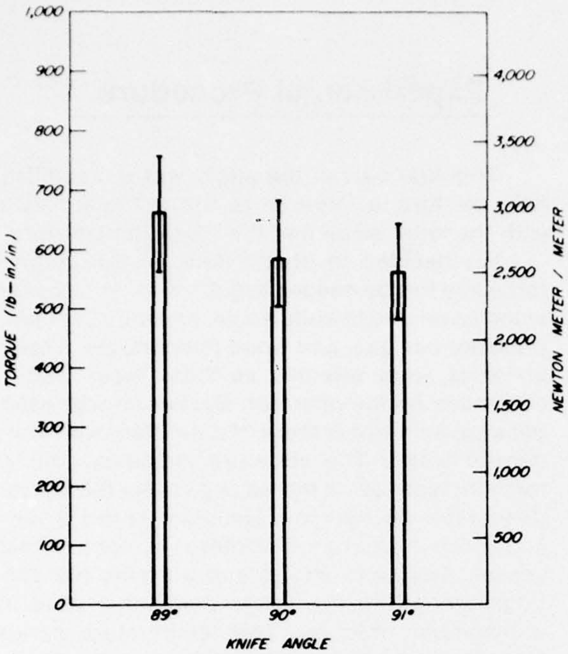

Figure 1.--Effect of knife angle on maximum torque required to cut basswood at 70° F into veneer 1/4 in. thick. The bar lead was 0.030 in. and the gap 90 pct of the veneer thickness. Block diameters 10 to 12 in.

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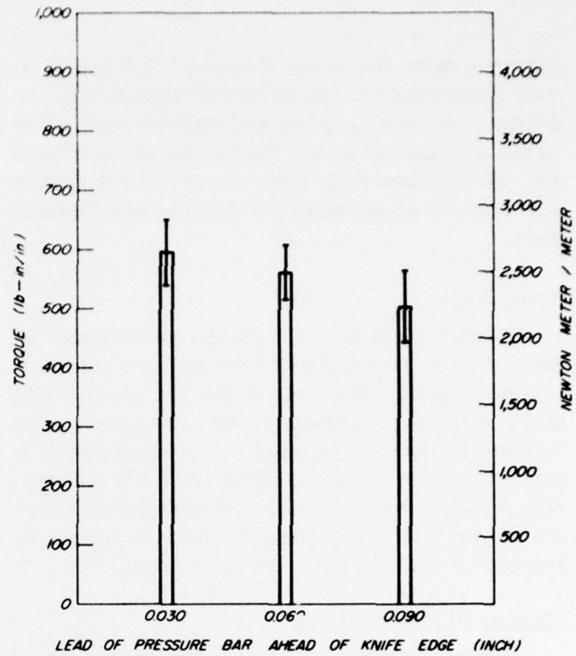

Figure 2.--Effect of lead of the pressure bar ahead of the knife edge on maximum torque required to cut basswood at 70° F into veneer 1/4 in. thick. The knife angle was 90° and the gap 90 pct of the veneer thickness. Block diameters 10 to 12 in.

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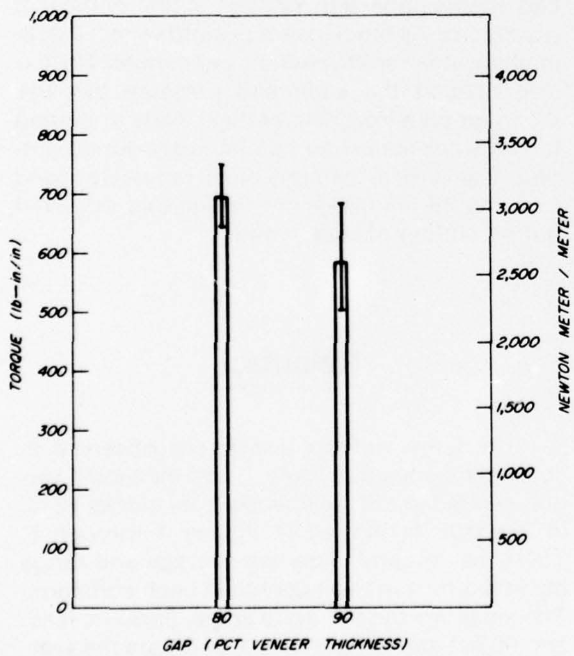

Figure 3.--Effect of the gap between the knife and the pressure bar on maximum torque required to cut basswood at 70° F into veneer 1/4 in. thick. The knife angle was 90° and the lead 0.030 in. Block diameter 10 to 12 in.

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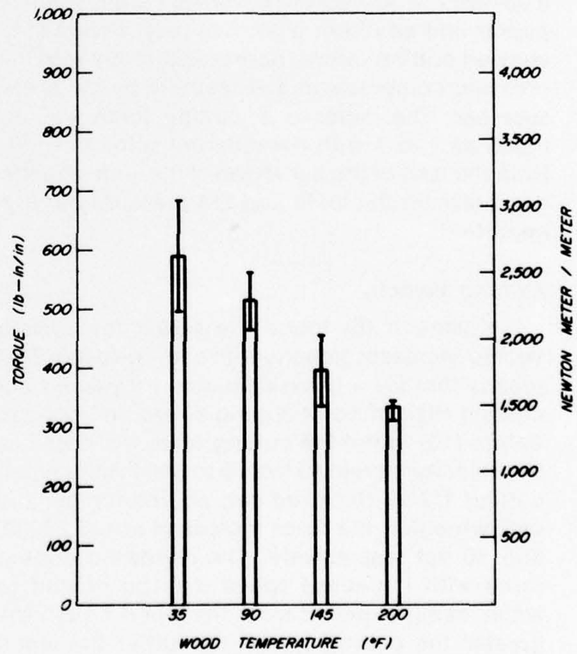

Figure 4.--Effect of wood temperature on the maximum torque required to cut basswood into veneer 1/4 in. thick. The knife angle was 90°, the lead 0.030 in., and the gap 90 pct of the veneer thickness. Block diameters 10 to 12 in.

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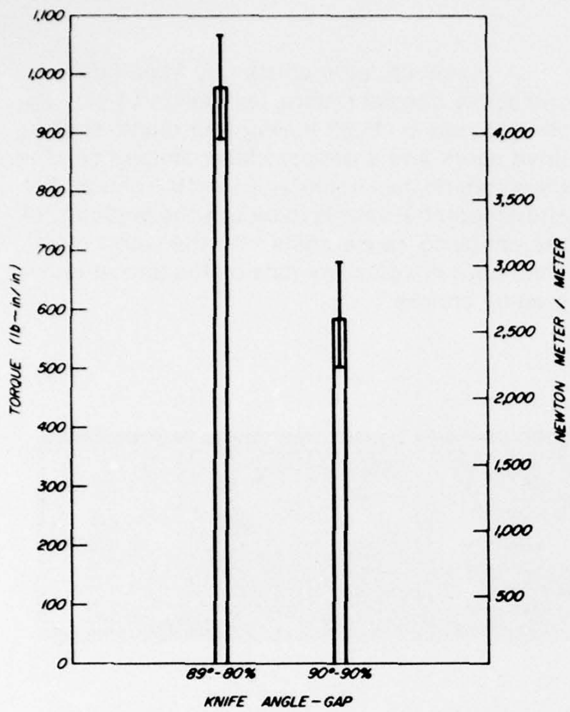


Figure 5.--Combined effect of changing knife angle and gap on maximum torque required to cut basswood at 70° F into veneer 1/4 in. thick. The lead in both cases was 0.030 in. Block diameters 10 to 12 in.

(M 144 388)

cutting forces as related to cutting a knot and through mineral stain is shown in figure 6.

The force of cutting generally built up during the first two or three revolutions of veneer and then remained essentially level for the duration of cutting. This meant maximum torque for cutting clear wood occurred at the maximum block diameter (10 to 12 in.) and then decreased with decreasing block diameter. Knots and mineral stain caused sharp increases in cutting force as shown in figure 6.

Knife angle.--The effect of different knife angles is plotted in figure 1. As expected, the lower knife angle resulted in the highest torque.

Lead of pressure bar.--The effect of lead of the pressure bar ahead of the knife edge is plotted in figure 2. Raising the bar to increase the lead reduced the torque required to cut veneer.

Gap of pressure bar.--The effect of a gap of either 80 or 90 pct of the veneer thickness between the knife and the pressure bar is shown in figure 3. The smaller gap or opening resulted in about 19 pct greater torque required to cut the 1/4-in. veneer.

Temperature.--Torques decrease with increases in wood temperature (fig. 4).

Knife angle and gap.--The effect of using a low knife angle (89°) and moderate gap (80 pct of veneer thickness) is compared to a 90° knife angle and a 90 pct gap in figure 5 and table 1. These higher lathe settings resulted in a reduction of maximum torque of about 40 pct. Both settings are commonly used in industrial practice. The cutting force can be reduced even more by using a 91° knife angle, a 0.090-in. lead, and a 90 pct gap (table 1).

Effect of cutting knots and mineral stain.--How cutting forces are related to a knot and mineral stain in the veneer is shown with part of a strip chart (fig. 6). The load in pounds is the total during cutting of a 6-in.-long block. The knot increased the cutting force about one-third over the force needed to cut clear wood. Surprisingly, the mineral stain increased the cutting force almost as much as the knot.

Discussion, I

Obviously, torque required to turn veneer bolts is highly variable. Torque increases linearly with bolt diameter and length. From the literature, torque required to cut veneer also increases markedly as the veneer thickness increases, as wood density increases, and probably increases some with increases in cutting speed.

Of the factors under control of the plant manager, temperature of the wood and the gap between the pressure bar and the knife seem most important. Knife angle and lead of the pressure bar can also be set to minimize the torque required to cut veneer.

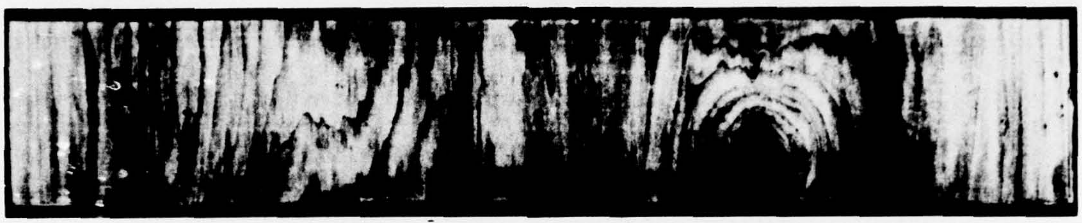
STAGE II.--MAXIMUM TORQUE DELIVERED BY CHUCKS WITH VARIOUS DESIGNS OF SPURS

Background

Visits to lathe manufacturers and plants producing wood veneer reveal a wide range of

spur configurations on the chucks. Some common drive spurs include chisel-shaped spurs set on the chuck radius or on a spiral from the center, circular spurs, semicircular spurs, and hexagonal spurs. In addition, the circumference of the chuck may have spurs to minimize lateral movement of the wood block during peeling. Many plants use chucks with spurs of their own design. For commercial chucks, self-cleaning and long life are strong considerations.

A report on lathe chucks by Maul (10) give subjective considerations for design of chucks. He suggests a chuck having four chisel-shaped drive spurs and a deeper chisel-shaped continuous spur on the circumference of the chuck. The circumferential spur is to reduce the tendency of the chuck to cause splits into the wood block. Maul does not give any data on the torque delivered by chucks.



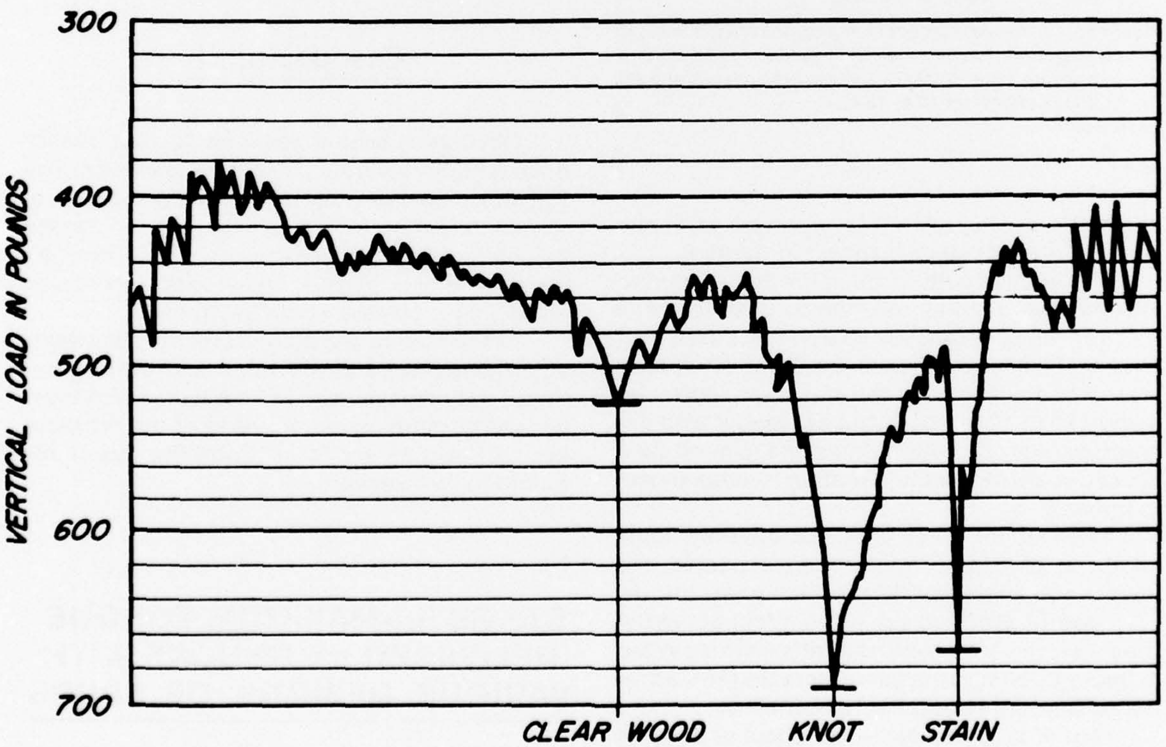


Figure 6.--Indication of how cutting forces (vertical load) varied on the strip chart during the cutting of clear wood, compared to knots and stain.

(M 143 568)

Table 1.--Maximum torque observed during cutting of clear 1/4-in.-thick basswood veneer from a block. (Diameter of 12 to 5-1/2 in.)

Wood temp.	Knife angle	Lead of bar	Gap of bar	Log number	Cutting force in clear wood	Radius of block	Maximum torque to cut clear wood	
°F	Degrees	In.	Pct		Lb force/in. of wood	In.	Lb in./in.	N-m/m
70	91	0.030	90	480	92	5.25	481	2,140
				481	111	5.80	645	2,869
70	90	.030	90	480	88	5.85	516	2,295
				481	104	6.01	624	2,776
70	89	.030	90	480	94	5.97	562	2,500
				481	126	6.01	759	3,376
70	90	.030	90	480	91	5.95	540	2,402
				481	110	5.93	650	2,891
70	90	.060	90	480	91	5.63	513	2,282
				481	102	5.95	609	2,709
70	90	.090	90	480	78	5.69	444	1,975
				481	95	5.91	565	2,513
70	90	.030	90	480	85	5.93	502	2,233
				481	114	5.97	682	3,034
70	90	.030	80	480	126	5.10	644	2,865
				481	132	5.67	750	3,336
35	90	.030	90	480	84	5.89	496	2,206
				481	117	5.85	685	3,047
90	90	.030	90	480	84	5.53	466	2,073
				481	97	5.83	565	2,513
145	90	.030	90	480	57	5.89	336	1,495
				481	80	5.74	457	2,033
200	90	.030	90	480	59	5.89	346	1,539
				481	56	5.75	323	1,437
70	89	.030	80	480	163	5.45	890	3,959
				481	181	5.89	1,067	4,746
70	91	.090	90	480	72	5.77	415	1,846
				481	77	5.77	446	1,984

Experimental Procedure,II

This second stage was to determine how *chuck design (fig. 7)* and wood temperature affect the torque that a block end will accept before failing by spin-out. The equipment used is shown in figure 8.

Three sets of data were generated. Sets 1 and 2 were made with clear, pith-free, 6- by 6-in. basswood blocks. Set 3 was obtained from 8- by 8-in. pith-centered basswood blocks. All sets involved three replicates--one from each tree.

Three block lengths were used. All blocks were originally 28-1/2 in. long. After they were used once, 8 in. from the failed ends were removed and the next run was with 20-1/4-in.-long blocks. For chucks 15 and 16, the blocks were again cut back 8 in., leaving a 12-in. block (12 in. was the maximum length we could broach slots required by chucks 15 and 16).

In exploratory runs, chucks 1, 4, and 5 split the 6- by 6-in. unsupported blocks. Furthermore, the maximum torque was about the same for all three chucks, indicating splitting controlled the results.

Set 1

Chucks 1 through 15 (table 2 and figs. 7 and 9) were screened in set 1. Three 6- by 6-in. blocks at 70° to 80° F were used with each chuck. The end of the block to be driven with the experimental chuck was supported by a 5-1/2-in. long metal clamp to prevent splitting of the wood during spin-out. This simulated larger diameter and longer blocks that would be more resistant to splitting.

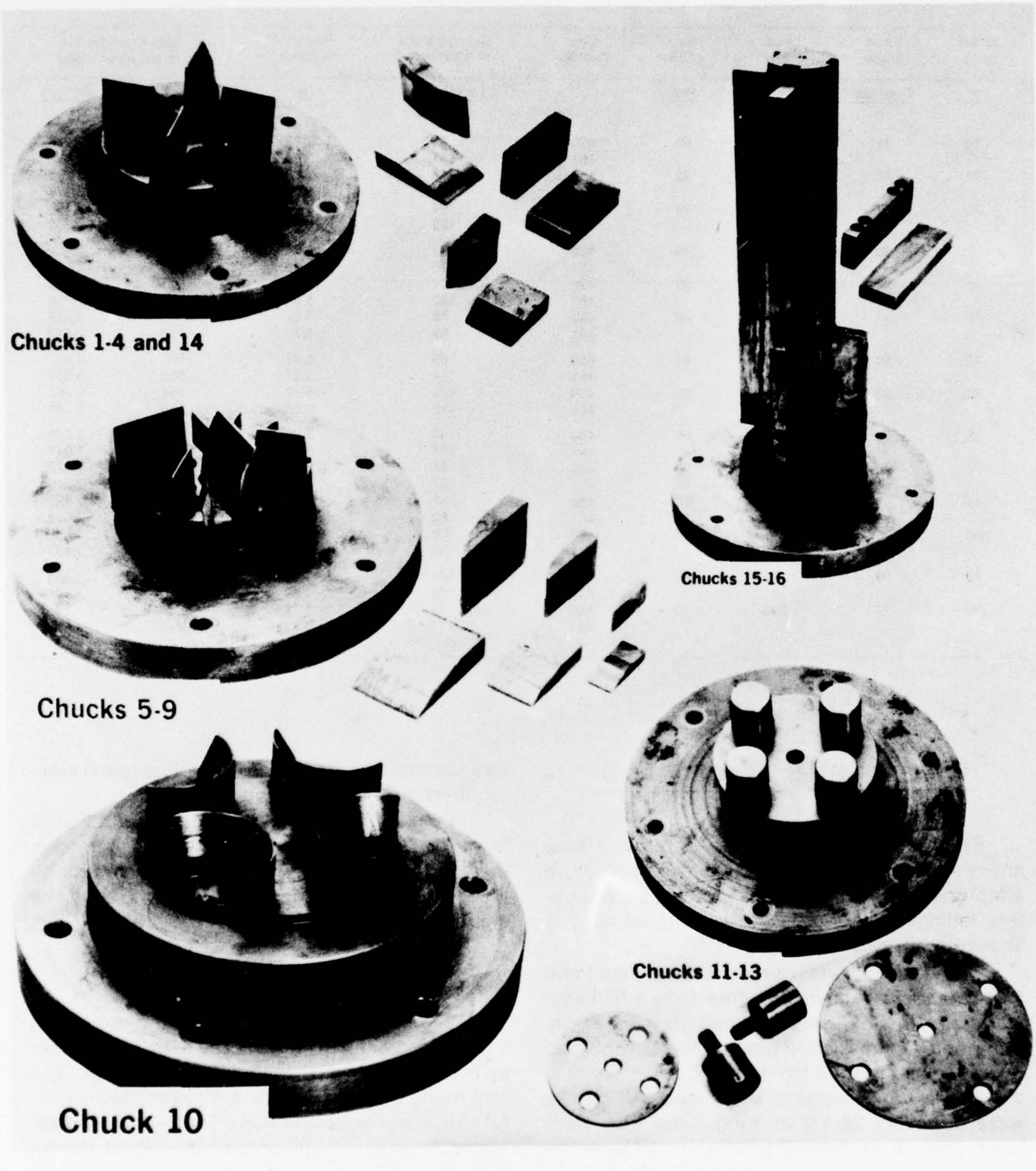


Figure 7.-- Chucks used in stage II of the study.
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Table 2. -- Description of chucks[1] used in stage II

Chuck number	Type of spurs	Number of spurs	Individual spur					Holes machined in wood blocks to accept spurs
			Depth	Width	Thickness		Chuck radius through center of spur or as driving surface of spur	
					Base	Tip		
			In.	In.	In.	In.		
1	Chisel	4	1-1/2	1-1/4	1/2	1/16	Center	No
2	Chisel	2	1-1/2	1-1/4	1/2	1/16	Center	No
3	Chisel	8	1-1/2	1-1/4	1/2	1/16	Center	No
4	Chisel	4	3/4	1-1/4	1/2	1/16	Center	No
5	Chisel	4	1-1/2	1-1/2	1/2	1/16	Driving surface	No
6	Chisel	4	1	1	3/8	1/16	Driving surface	No
7	Chisel	8	1/2	1/2	3/16	1/16	Driving surface	No
8	Chisel	8	(Spurs used in chucks 5 and 6)			1/16	Driving surface	No
9	Chisel	16	(Spurs used in chucks 5 6, and 7)			1/16	Driving surface	No
10	Semicircular	4	1	1	3/8	1/16	Not applicable	No
11	Cylindrical	4	1	1	1	1	Center	Yes
12	Cylindrical	4	1	1	1	1	Center	Yes
13	Cylindrical	4	1	1	1	1	Center	Yes
14	Rectangular	4	1-1/2	1-1/4	1/2	1/2	Center	Yes
[2]15	Rectangular	4	4	1	1/2	1/2	Center	Yes
[2]16	Rectangular	4	12	1	1/2	1/2	Center	Yes

[1]*All chucks 4 in. in d[illegible]er except 11 and 13, which are 3 and 5 in., respectively.*

[2]*Spurs on chucks 15 and 16 extend laterally from a steel shaft 2 in. in diameter.*

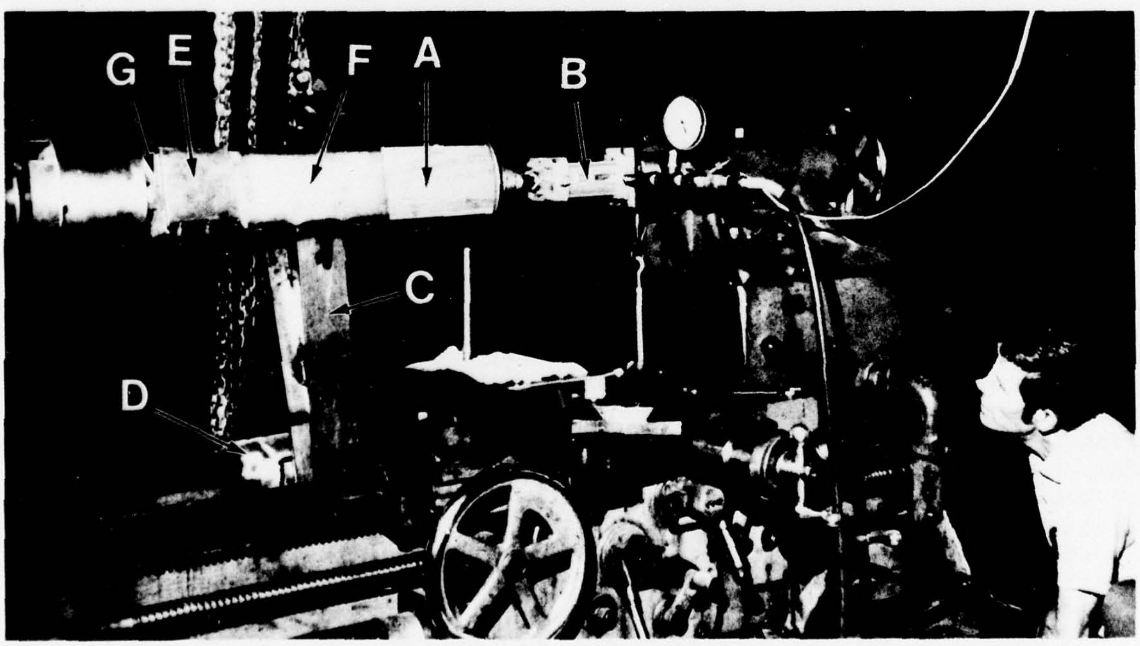

Figure 8.--Overall spin-out set-up. A is the test block; B is the cylinder that provides end pressure; C is the lever arm attached to the collar (F) that slips over the wood block; D is the load cell that measures the force required to spin-out the block; E is a clamp used with some blocks to prevent splitting; F is the collar; and G is the driving chuck.

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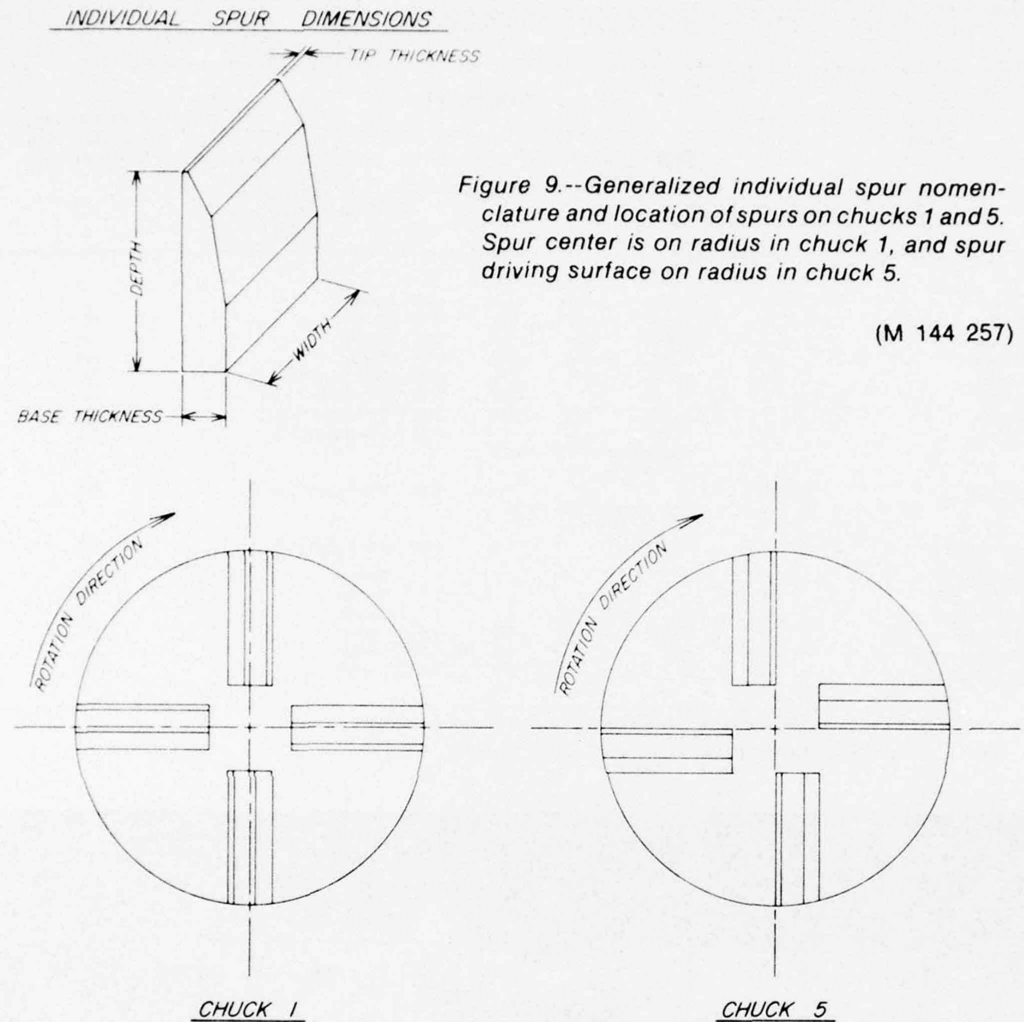

Figure 9.--Generalized individual spur nomenclature and location of spurs on chucks 1 and 5. Spur center is on radius in chuck 1, and spur driving surface on radius in chuck 5.

(M 144 257)

The block was then slipped into a collar 6 in. square and 1 ft long (fig. 8F). Welded to the collar is a 22-in. lever arm that contacts a load cell (fig. 8D). A hand-activated pump applied hydraulic pressure through a cylinder (fig. 8B) to set the spurs on chucks 1 through 10 to within 1/16 in. of the face of the driven chuck. Blocks used with chucks 11 to 15 were machined to accept the spurs and so required little end pressure to set the spurs. The end pressure was adjusted to 3320 lb just prior to all spin-out runs.

The opposite end of the block was centered on a dummy chuck that rested on a thrust bearing. Thus the torque measured was that delivered by one chuck only (fig. 8G).

The driven chuck was turned at a rate of seven revolutions a minute until the torque peaked and dropped off. This occurred at about 1/8 of a revolution of the chuck. A strip chart marked with light galvanometers gave a continuous record of torque and end pressure during spin-out.

Obviously, this procedure is not typical of a commercial veneer cutting operation but it was designed to reduce variability and give meaningful results. Consequently, results are reported only as a percent of the torque delivered by a "standard" chuck. The torque values for the standard chuck were given a value of 100 pct and the torque values of the other chucks were converted to a percent of this standard. The chuck

chosen for the standard is number 1 in table 2. Six runs, two for each log, were made with the standard chuck. All other chucks in table 2 had three replicate runs using one block from each of three trees.

Set 2

Only the standard chuck was used in set 2 and the wood temperature was varied from 35° to 200° F. Otherwise the procedure was the same as for set 1. Torque values for wood blocks at 75° F were considered 100 pct and the torque values for blocks at other temperatures compared to this standard.

Set 3

Set 3 used pith-centered basswood blocks 8 by 8 in. in cross section without an end clamp to prevent splits. An exception is chuck 16 which may be described as a key-way chuck with a spline drive (fig. 10). The spurs of chuck 16 extended through the 12-in.-long block. Six inches of the block were unsupported but the other 6 in. were in the collar that transmitted the force needed to cause spin-out.

The collar holding the block was 8 in. square but otherwise the experiments were run the same as set 1. Maximum torque values are given in pound-inches and Newton-meters for the six chucks used in the third set. A record was also made of whether the blocks split during spin-out. After spin-out, the 8-in. failed ends of representative blocks were sectioned lengthwise to observe wood failure.

Results, II

The results are given in figures 11 to 13 and table 3.

Set 1

Increasing the number of spurs from two to four to eight (chucks 2, 1, and 3) resulted in an increase in torque with the 6- by 6-in. end-clamped blocks (fig. 11). Eight was the maximum number of spurs that could be fitted in this chuck (fig. 7 and table 2).

Since increasing the number of spurs increased the torque, a new chuck was built that would hold more spurs. To do this the spurs were made of different sizes. The shorter, thinner, and narrower spurs (chucks 6 and 7) used by themselves resulted in lower torque when compared to the larger spurs (chuck 5). The smallest spurs (chuck 7) bent during the first run. These spurs were made with 10-18 cold roll steel. Hardened steel spurs would be stronger and might give higher torque values. Adding small and large spurs in the same chuck (chucks 8 and 9) resulted in a slight decrease in torque when compared to using the four largest spurs alone (chuck 5).

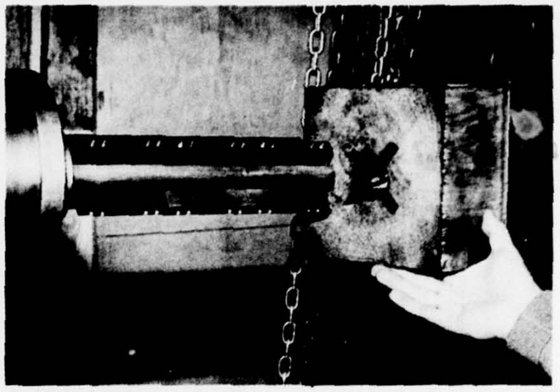

Figure 10.--Machined block just prior to inserting chuck 16. (M 144 064-11)

There was little difference in torque delivered with spurs having the chuck radius through the center of the spur (chuck 1) or on the driving surface of the spur (chuck 5), figures 8, 9, and 11.

The l-in.-deep semicircular spurs (chuck 10) delivered slightly less torque than the 1-1/2-in. deep chisel spurs (chuck 1) and about the same torque as the 3/4-in.-deep chisel-shaped spurs (chuck 4).

Chucks 11, 12, and 13 show the effect of chuck diameter using four identical cylindrical spurs for each chuck. Holes were drilled in the block ends to accept these spurs. The gain in torque from 4 to 5 in. in diameter was greater than from 3 to 4 in. in diameter. The area between spurs as well as rolling shear may be a factor in greater torque for larger diameter chucks. Torque delivered by the 1- by 1-in. cylindrical spurs (chuck 12) was only half that delivered by the standard chuck 1 with 1-1/2-in.-deep by 1-1/4-in.-wide chisel-shaped spurs. Chucks 1 and 12 are both 4 in. in diameter.

Slots were mortised in the block ends to accept the rectangular spurs, chuck 14. These rectangular spurs are the same depth and width as the chisel spurs in chuck 1 and resulted in about the same torque.

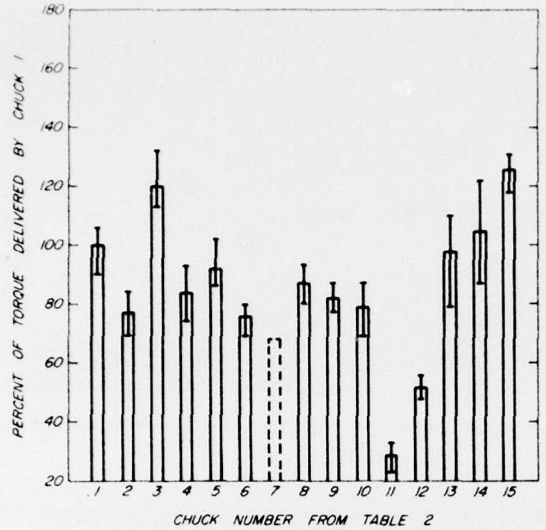

Figure 11. -- Comparative torque obtained from 15 chucks described in table 2. All runs were made in clear 6- by 6-in. basswood blocks that were held in a clamp to prevent splitting. Torque for chuck 1 was assigned a value of 100 pct and the others compared to it.

(M 144 383)

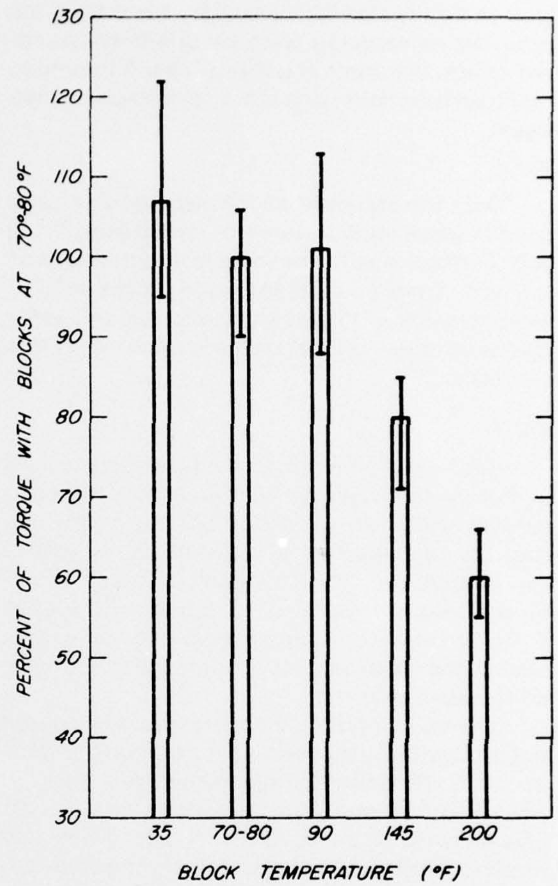

Figure 12.--Comparative torque obtained with basswood blocks at various temperatures. Blocks at 70° to 80° F were assigned a value of 100 and blocks at other temperatures were compared to this. All runs were with chuck 1 in clear 6-by 6-in. basswood blocks held in a clamp to prevent splitting.

(M 144 384)

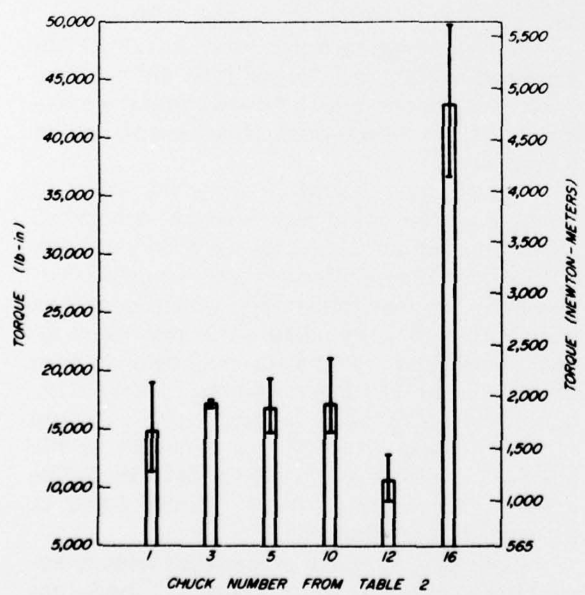

Figure 13.--Maximum torque obtained with six chucks in pith-centered 8-by 8-in. basswood blocks at about 70° F.

(M 144 393)

Table 3. -- Maximum torque obtained with six different chucks in pith-centered 8 x 8 in.-basswood blocks.

Chuck number	Log number	End pressure to set spurs		Maximum torque prior to spin-out		Did block split
		Lb	kg	Lb - in	Nm	
1	490	6,474	2,943	19,048	2,152	No
1	491	4,814	2,188	11,363	1,284	No
1	492	5,395	2,452	14,287	1,614	No
	Av.	5,561	2,528	14,899	1,683	
3	490	12,450	5,659	17,582	1,987	Yes
3	491	10,458	4,754	17,216	1,945	No
3	492	11,620	5,281	16,850	1,904	No
	Av.	11,509	5,231	17,216	1,945	
5	490	9,296	2,037	19,414	2,194	Yes
5	491	6,142	2,798	16,485	1,863	No
5	492	7,055	3,207	14,652	1,656	Yes
	Av.	7,498	2,681	16,850	1,904	
10	490	11,039	5,017	20,147	2,277	No
10	491	9,794	4,452	14,652	1,656	No
10	492	8,881	4,037	16,485	1,863	No
	Av.	9,905	4,502	17,095	1,932	No
12	490	0	0	12,823	1,449	No
12	491	0	0	8,791	993	No
12	492	0	0	10,252	1,159	No
	Av.	0	0	10,622	1,200	
16	490	0	0	49,808	5,628	Yes
16	491	0	0	42,482	4,800	Yes
16	492	0	0	36,630	4,139	Yes
	Av.	0	0	42,973	4,856	

The blocks for chuck 15 were drilled and broached to accept the spurs. The spurs extended radially from the surface of a 2-in.-diameter steel shaft. Each spur engaged 1 by 4 in. of block surface. The torque was about one-fourth greater than that delivered by the standard chuck 1 with 1-1/2- by 1-1/4-in. chisel-shaped spurs. However, the blocks used with chuck 15 split even though they were end clamped.

Set 2

Torque decreased as the temperature increased on the 6- by 6-in. end-clamped blocks (fig. 12). Temperatures above 90° F appear to significantly reduce the torque deliverable to blocks. The loss was 20 pct at a temperature of 145° F and 40 pct at a temperature of 200° F. This loss is slightly less than the loss of strength properties of heated wood as shown on page 4-33 of the Wood Handbook (14).

Set 3

Results on pith-centered 8- by 8-in. blocks without end-clamps include the end pressure needed to set the spurs, the maximum torque developed, and whether the blocks split when evaluated (table 3).

End pressure required to set the spurs was maximum with chuck 3 that has eight chisel-shaped spurs, followed by chuck 10 that has semicircular spurs. In all cases, within a set of three blocks, those from log 490 required the most end pressure to set the spurs and also had the highest torque. Apparently, the compressive strength of wood is an indicator of the amount of torque a block will accept before spin-out.

Torque delivered by chucks 1, 3, 5, and 10 overlapped. However, averages for chucks 3, 5, and 10 were slightly higher than 1 (fig. 13). These are typical of industrial chucks and indicate that there is not a great difference among them. Chuck 3 with eight spurs had a smaller range of torque values than the other chucks. As only three blocks were used, this may be a chance occurrence.

Chuck 12, with cylindrical spurs in 1-in. predrilled holes, was low in torque as in earlier experiments.

Chuck 16 with four rectangular spurs, each in contact with 1 by 12 in. of block surface (figs. 10 and 13), gave markedly higher torque values.

However, all of these blocks split.

Chucks 3 and 5 with chisel-shaped spurs caused splits in some blocks and not in others. A larger sample is needed to assess the tendency of the various chucks to cause the wood blocks to split. Splitting is just as limiting as spin-out.

Wood failure in most spun-out blocks occurred by tangential or rolling shear in a cylinder about 4 in. in diameter and about 3 to 4 in. deep (fig. 14). Failure also occurred by cross-grain shear or tension parallel to the grain about 3 to 4 in. deep in the block. Initial deformation is probably by compression perpendicular to the grain. With chuck 16 failure occurred by splitting followed by rolling shear.

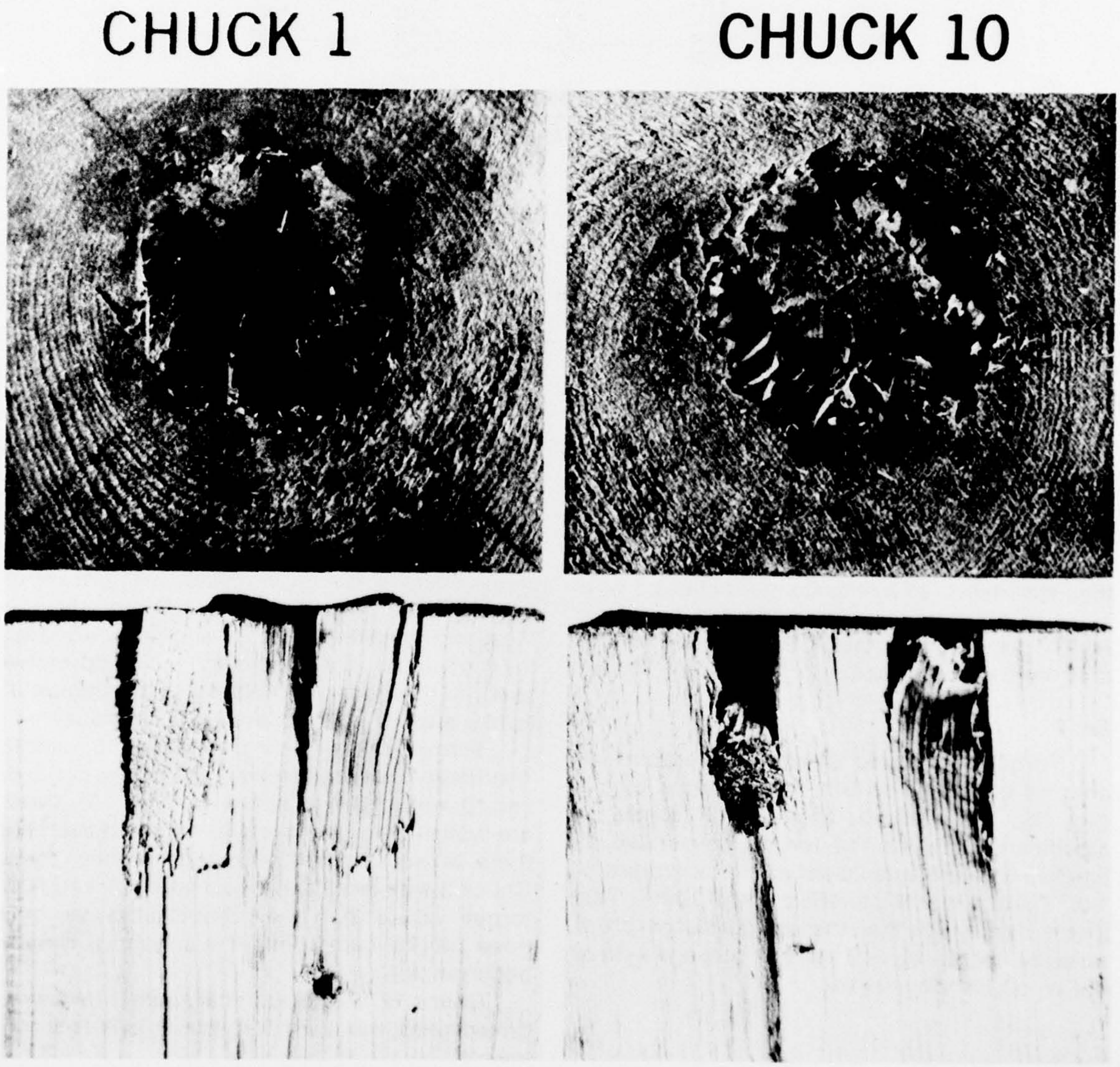

Figure 14.--End and longitudinal sections of blocks failed by chucks 1 and 10. Failure is by rolling shear and by tension parallel to the grain.

(Composite of M 144 068, 066)

Discussion, II

Shear strength parallel to the grain for green basswood is about 600 lb/in.^{2}. Tangential or rolling shear is about one-fourth of this, or 150 lb/in.^{2}. Suppose we assume failure with chuck 16 is entirely due to rolling shear at a 4-in. diameter. The shear area is 3.14 by 4 by 12 $\simeq$ 150 in.^{2}. The resistance to torque is the shear area (150 in.^{2}) times rolling shear strength (150 lb/in.^{2}) times 2-in. radius, or 45,000 lb-in. Table 3 shows the measured torque for chuck 16 varied from 36,000 to 50,000 lb-in.

With chucks 1, 3, 5, and 10 the area of rolling shear was about 3 in. deep, or one-fourth that of chuck 16. Rolling shear would then contribute about 11,000 lb-in. The higher torques observed are probably due to cross-grain shear or tension parallel to the grain in addition to rolling shear.

The results indicate why deep spurs, which cause rolling shear to occur over a wider area than shallow spurs, increase the torque. Increasing the number of deep spurs may result in more cross-grain shear and so increase torque. Small spurs together with large spurs are riding in already failed wood and do not contribute to torque.

Chuck 10 developed lower torque than chuck 1 in clear end-clamped blocks (fig. 11) but developed higher torque than chuck 1 when used in pith-centered unclamped blocks (fig. 13). A larger sample is needed to determine if there is any significant difference among chucks 1, 3, 5, and 10.

STAGE III.--POSSIBLE SUPPLEMENTAL TORQUE FROM FRICTION DRIVE ON BLOCK SURFACE

Background

When discussing the problem of spin-out inevitably some colleague will suggest driving from the block surface. Two German patents, DRP 470-554 K1 38i and BPA Sch. 15-903-X11/38i,[3] describe methods of driving veneer blocks from the cylindrical surface. However, as far as we know, these methods have never been used to peel wood blocks into veneer. Depending on the system used, the block may have to be turned to a cylinder by conventional means before the supplemental peripheral drive is used.

A potential problem in driving from the block surface is the low coefficient of friction between steel and wood. Atack and Tabor (1) found that sliding friction between wet balsam fir and steel varied erratically from 0.2 to 0.5 due to small amounts of fatty acid esters in the wood. Extracted wet balsam wood and curved steel sliders had a coefficient of friction of about 0.5.

Atack and Tabor also showed that friction between wood and steel, when a curved steel slider is pulled across a flat wood surface, is the sum of two independent terms:

$$F_S = F_D + F_A$$

F_D is the force to deform the wood (this is the same as rolling friction) and F_A is the force required to overcome interfacial adhesion between the slider and wood.

For drive rolls the situation is different than the experiment described by Atack and Tabor. The rolling friction must be overcome before the block can move with respect to the driven roller. The surface friction or interfacial adhesion must be greater than the rolling friction or the block will have no tendency to move. The usable friction F, therefore, is:

$$F = F_A - F_D$$

Lemoine and Koch (7) report the static coefficient of friction parallel to the grain of dry slash pine and red oak to be 0.1 with smooth steel, 0.8 to 0.9 with 220 grit garnet paper, and 0.9 to 1.0 for a proprietary polyurethane of 65 to 70 durometer hardness. Durometer is an ASTM measure of the hardness of rubber and other similar materials. Data are not given for the coefficient of friction with wet wood.

Experimental Procedure, III

This third stage examined the possibility of auxillary torque input to the block by friction drive on the block surface.

The coefficient of friction was determined

[3]Specific information on patents available from German Consulate, Washington, D.C.

between green wood specimens and a roller bar about 1-1/4 in. in diameter. The green specimens were clear and flat-grained material of basswood, Douglas-fir, and red oak at room temperature. Three bar surfaces were used--smooth steel, 40 grit emery cloth, and 1/16-in.-thick rubber with a durometer of 60 to 65. The rubber and emery cloth bars were made by gluing 3/4-in. wide strips of these materials to the 1-1/4-in.-diameter stainless steel bar. The strips of rubber or emery cloth fit between the cam followers which support the bar. Static friction, rolling friction, and dynamic friction were measured at three load levels--50, 100, and 150 lb/in. of contact.

Figure 15 shows the experimental set-up with the rubber-surfaced bar. Test blocks were held in a vise which in turn was bolted to a two-component load cell. A chain-driven roller bar was fastened to the milling machine overarms. The roller bar was supported by two rows of anti-friction cam followers. With the chain drive removed, the bar was free to turn as a specimen passed under it.

One specimen, 4 by 4 by 4 in., of each species was used for each set of conditions. Prior to each run the surface of the block was renewed with three cuts of about 0.020 in.

In all experiments the milling machine table was raised until the wood specimen contacted the roller bar. The table was then raised further to obtain the desired average vertical load of approximately 50, 100 or 150 lb/linear in. of bar contact.

For static friction, the specimen was loaded vertically and the bar turned at a surface speed of about 0.05 in./sec. The wood specimen remained stationary and the maximum horizontal load was recorded. The coefficient of friction was computed from the ratio of horizontal to vertical load.

The chain drive was removed when measuring rolling friction. The wood block was loaded against the roller bar to determine the machine index needed for a given load. The wood block was then moved below and to one side of the roller bar; after reindexing, the block was passed under the free rolling bar at a speed of 1 in./sec. The vertical and horizontal loads were measured during this pass and the "negative" coefficient of friction computed.

Dynamic friction was measured by moving a preindexed wood block across the surface of a powered roller bar at 1 in./sec. The roller bar surface was driven at about 1.2 in./sec or slightly faster and in the same direction as the wood block. The coefficient of friction was computed from the recorded vertical and horizontal loads.

Results, III

Results are given in table 4 and figures 16, 17, and 18.

Static Friction

Static friction (fig. 16) varied with wood species, surface on the roller bar, and load on the roller bar. In general, friction increased slightly from basswood to Douglas-fir to red oak.

Emery cloth had the highest coefficient of friction, smooth steel the lowest, with smooth rubber intermediate.

The load on the steel bar had little effect on coefficient of friction. With emery cloth the coefficient of friction was high for loads of 50 and 100 lb/in. of bar but dropped off with a load of 150 lb. With the rubber surface there was a consistent drop in coefficient of friction with changing normal loads of 50, 100, and 150 lb/in. of bar.

Rolling friction

Rolling friction is shown as negative values in figure 17 because a nondriven roller loaded against the surface of a veneer block increases the torque needed to turn the block. These data show why a nondriven backup roll on a lathe may increase the percentage of blocks that spin-out.

Dynamic Friction

Of things tried in this study, coefficient of friction with the overdriven bar (fig. 18) probably best indicates what torque could be delivered to an operating veneer lathe. Emery cloth gave a coefficient of friction of 0.6 or better, rubber about 0.3 or better, and steel 0.1 or better.

Figure 19 shows that the overdriven bar with emery cloth surface slightly eroded the wood, particularly at higher pressures. The rubber slightly darkened the wood. Smooth steel left no marks

Figure 15.--Setup for measuring friction between a driven roller bar and a block of wood. The block is held in a vise which is bolted to a two-component load cell. The bar has 3/4-in wide strips of rubber glued to it. Coefficient of friction is being measured between the rubber and wood surfaces.
(M 144 064-4)

Discussion, III

Theoretically there should be no change in coefficient of friction with different loads.However, if the roller bar indents the wood there is internal friction in the wood (rolling friction) which must be overcome before there is any usable driving friction. The lower coefficient of friction with higher loads on wet wood may also be due to more water being forced out at higher pressure and acting as a lubricant.

At any rate the results indicate that a large-diameter roll with a moderately soft surface and relative low load per inch of contact would be desirable for the driving roll. Since the rubber worked best at a pressure of 50 lb/in., a possible system would use two overdriven rubber-surfaced rolls, each loaded at 50 lb/in. of contact. This should result in a coefficient of friction of 0.4 to 0.5.

Table 4. -- Friction related to type of roller bar

Type of test	Steel			Rubber			Emery cloth		
	Vertical load	Horizontal load	Coefficient of friction	Vertical load	Horizontal load	Coefficient of friction	Vertical load	Horizontal load	Coefficient of friction
	Lb/in.	Lb/in.		Lb/in.	Lb/in.		Lb/in.	Lb/in.	
				BASSWOOD					
Static	47.5	7.5	0.158	37.8	22.2	0.587	50.0	35.5	0.710
	95.0	17.5	.184	88.9	31.1	.350	100.0	71.1	.711
	140.0	27.5	.161	151.1	44.4	.294	133.3	71.1	.533
Rolling	57.5	-7.5	-.130	57.8	-6.7	-.116	53.3	-8.9	-.167
	106.3	-15.0	-.141	111.1	-13.3	-.120	115.6	-8.9	-.077
	160.5	-27.5	-.171	168.9	-20.0	-.118	173.3	-17.8	-.103
Dynamic	55.0	10.0	.182	57.8	24.4	.422	57.8	44.4	.768
	98.8	12.5	.127	102.2	35.6	.348	111.1	80.0	.720
	103.8	15.0	.092	173.3	42.2	.244	183.1	111.1	.607
				DOUGLAS-FIR					
Static	50.0	8.8	.176	33.3	22.2	.666	37.8	31.1	.822
	90.0	15.0	.167	93.3	35.6	.382	84.4	71.1	.842
	140.0	25.0	.179	151.1	44.4	.294	146.7	88.9	.606
Rolling	55.0	-7.5	-.136	57.8	-4.4	-.076	57.8	-8.9	-.154
	100.0	-15.0	-.150	108.9	-11.1	-.102	102.2	-13.3	-.130
	157.5	-30.0	-.190	164.4	-22.2	-.135	160.0	-26.7	-.167
Dynamic	52.5	7.5	.143	57.8	28.9	.500	47.6	35.5	.746
	88.8	12.5	.141	93.3	40.0	.429	97.8	71.1	.727
	136.3	12.5	.092	160.0	57.8	.361	137.8	93.3	.677
				RED OAK					
Static	50.0	17.5	.350	37.8	22.2	.587	53.3	44.4	.833
	95.0	18.8	.198	97.8	33.3	.340	102.2	88.9	.870
	142.5	30.0	.211	164.4	44.4	.270	155.6	93.3	.600
Rolling	62.5	-5.0	-.080	53.3	-6.7	-.126	75.6	-8.9	-.118
	108.8	-10.0	-.092	102.2	-6.7	-.066	120.0	-17.8	-.148
	157.5	-15.0	-.095	168.9	-13.3	-.079	173.3	-17.8	-.103
Dynamic	65.0	15.0	.231	57.8	28.9	.500	64.4	44.4	.689
	117.5	23.8	.203	177.8	62.2	.350	128.9	88.9	.689
	163.8	27.5	.168	240.0	73.3	.305	226.7	137.8	.608

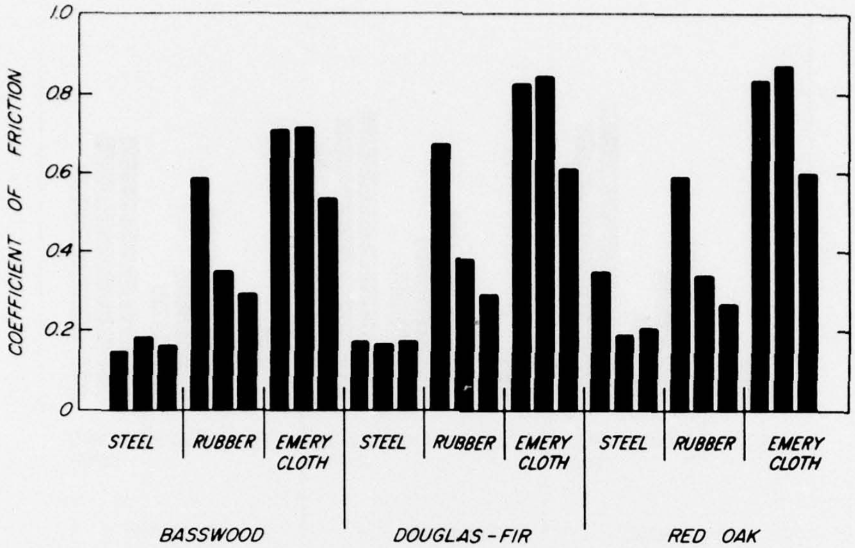

Figure 16.--Static friction as related to wood species, roller-bar surface, and normal load on the roller bar. The three bars in each set (reading left to right) represent friction obtained at loadings of 50, 100, and 150 lb/linear in. of roller bar in contact with wet wood.

(M 144 386)

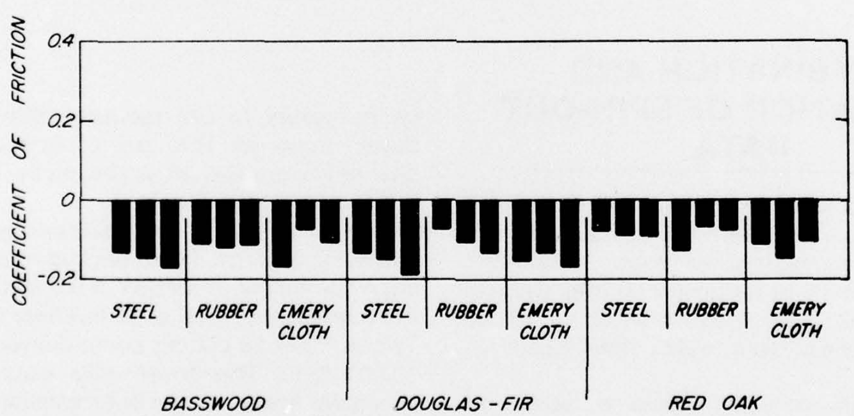

Figure 17.--Rolling friction as related to wood species, roller-bar surface, and normal load on the roller bar. The three bars in each set (left to right) represent "negative" friction obtained at loadings of 50, 100, and 150 lb/linear in. of roller bar in contact with wet wood.

(M 144 385)

Cutting force for peeling 1/4-in.-thick basswood veneer was about 100 lb/in. of wood (table 1). Two driven back-up rolls, each loaded at 50 lb/linear in. of contact with the bolt and having a coefficient of friction of 0.5, could supply one-half of the torque needed to cut this veneer.

Further evaluations should be made with other rubber or polyurethane surfaces to optimize the coefficient of friction with wet wood.

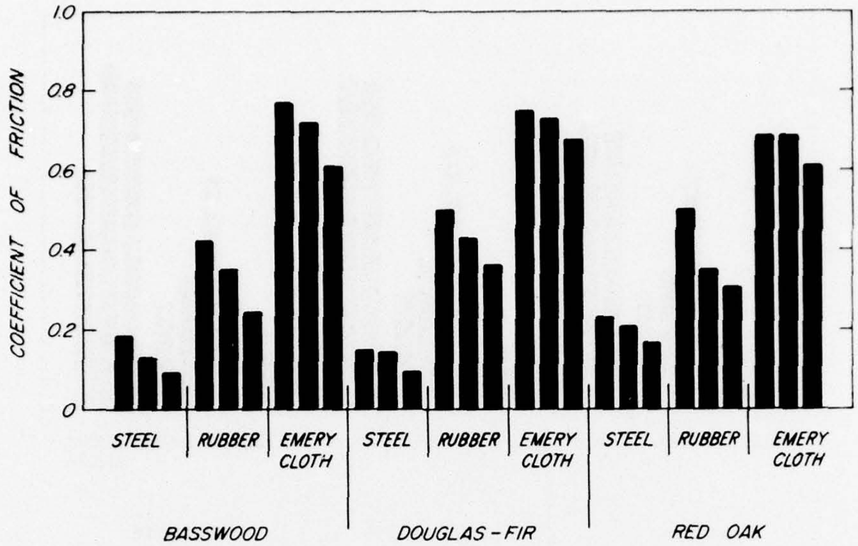

Figure 18.--Dynamic friction as related to wood species, roller bar surface, and normal load on the roller bar. The three bars in each set (left to right) represent friction obtained at loadings of 50, 100, and 150 lb/linear in. of roller bar in contact with wet wood.
(M 144 387)

COMBINATION AND APPLICATION OF SPIN-OUT DATA

If we assume a cutting force of 100 lb/in. of block length (table 1) then a 100-in. block of basswood 20 in. in diameter would require 100 × 100 × 10 = 100,000 lb-in. of torque for cutting. Chucks 1, 3, 5, and 10 (table 3) delivered about 16,000 lb-in. Two of the chucks could deliver 32,000 lb-in. of torque.

These calculations indicate a basswood block 20 in. in diameter and 100 in. long, placed in a lathe having No. 3 chucks and set to cut 1/4-in.-thick veneer, would almost certainly spin-out. If block diameter was reduced to 10 in., the torque required to cut 1/4-in.-thick veneer would be 50,000 lb-in. and the block would still spin-out. If the block were also shortened to 50 in., then cutting torque would be 100 × 50 × 5 = 25,000 lb-in. Two chucks delivering 32,000 lb-in. should be able to sucessfully turn sound blocks into 1/4-in.-thick veneer.

Assume 1/4-in and thicker veneer is to be peeled from 100-in. long blocks to a core diameter of 4-1/2 in. In that situation, it will probably be necessary to use radically different procedures, such as the use of nonconventional chucks like number 16, or driving by friction from the surface of the block.

Assume a lathe was equipped with number 16 chucks and two driven backup rolls, each having a coefficient of friction of 0.5 and bearing on the block with a load of 50 lb/linear in. of block. Two number 16 chucks could deliver a constant 70,000 lb-in. The driven rolls would deliver a gradually lower torque with smaller block diameters. Less torque would also be needed to cut veneer from smaller block diameters. For a 100-in. block at a 20-in. diameter they would deliver 10 × 100 × 50 × 2 × 0.5 = 50,000 lb/in. The combined drive would, therefore, be 70,000+ 50,000 = 120,000 lb-in., which should overcome the 100,000 lb-in. of torque required for cutting. Larger retractable chucks would give a margin for safety.

At a 10-in. diameter this same block would be driven by 70,000 lb-in. from the number 16 chucks plus 5 × 100 × 50 × 2 × 0.5 = 25,000 lb-in. from the drive rolls or a total of 95,000 lb-in. to overcome a cutting resistance of 50,000 lb-in.

The preceding example is not suggested as a practical method. As explained earlier more research is needed with chucks similar to number 16 to establish how much torque can be produced without splitting the blocks. Similarly, more information is needed to determine the feasability of driving by friction from the rounded block surface.

The information from this study does show that only relatively small gains in torque can be obtained by modifying the shape and size of spurs on conventional chucks. Radically different methods of supplying torque to turn veneer blocks should be studied if the goal is to cut 1/4-in. and thicker veneer from 100-in.-long blocks to 4-1/2-in.-diameter cores.

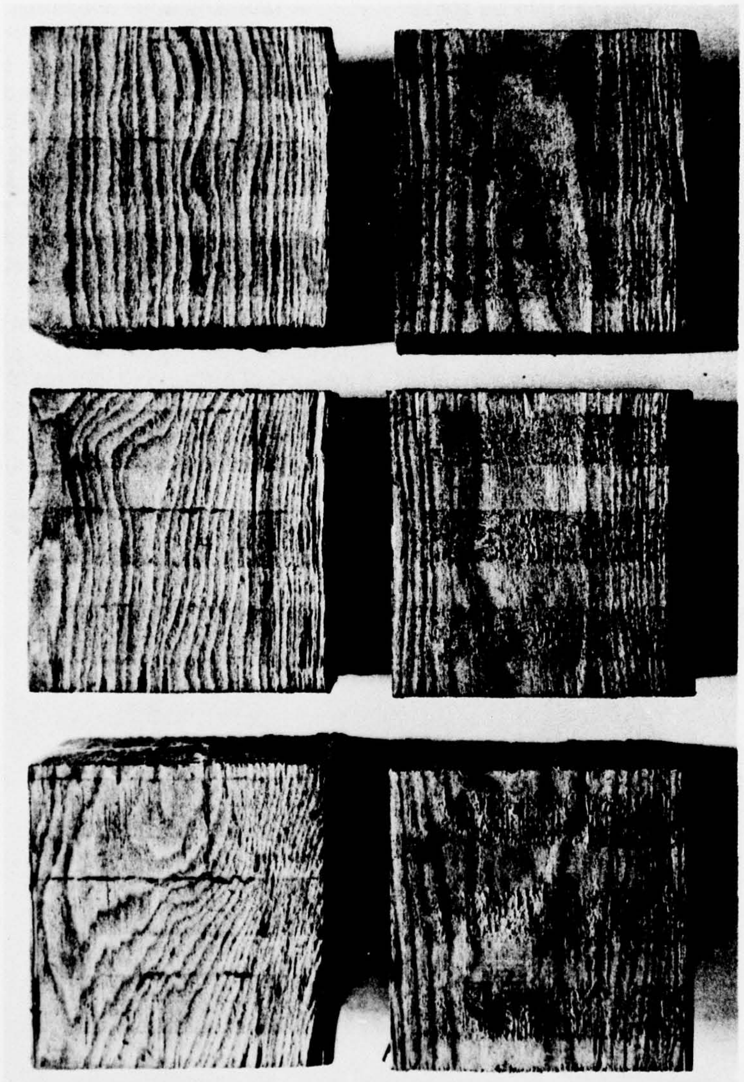

Figure 19.--Surfaces of Douglas-fir after the dynamic friction evaluation. Blocks on the left were evaluated with a rubber surfaced bar and those on the right with emery cloth. Normal pressure between the block and the bar was approximately 50, 100, and 150 lb/linear in. from top to bottom.

(M 144 063)

CONCLUSIONS

(1) Torque required to cut 1/4-in. basswood at room temperature can be varied by a factor of 2 to 1, depending on the setting of the lathe knife and pressure bar.

(2) Increasing wood temperature from 70° to 200° F reduced torque required to cut 1/4-in.-thick veneer by 40 pct. This increase in temperature also reduced the torque that can be transferred by the chuck by about 40 pct. The best condition, therefore, is to have the bulk of the block warm and the ends of the block cool. The worst condition is to have the bulk of the block cool and the ends hot. This can happen if the block heating is at a high temperature for too short a time. Decrease in spin-out reported by Fraser when going to a longer heating time was probably due to lower cutting forces with more uniformly warm blocks. Cooling the ends of heated blocks with a cold water spray prior to peeling is a step in the correct direction but is limited because the cooling rate of wood is slow. A longer heating time at the preferred cutting temperature is a better method for reducing spin-out.

(3) A 4-in.-diameter chuck with four chisel spurs, 1-1/2 in. deep, delivered about the same torque as four semicircular spurs 1 in. deep. These two chucks are typical of those used in industry.

Increasing the number of 1-1/2-in.-deep chisel spurs from four to eight resulted in a slight increase in torque. However, adding smaller spurs to a chuck having four spurs 1-1/2 in. deep resulted in a slight loss in torque.

A radically different chuck consisting of four rectangular spurs 1 in. wide by 12 in. deep, and attached to a 2-in.-diameter steel shaft, about doubled the torque delivered by four chisel-shaped spurs 1-1/2 in. deep. This radically different chuck required machining the block ends to accept the 2-in. steel shaft and spurs. It also caused massive splits in all blocks tested. More research is needed to determine if this is a viable method of increasing torque to turn veneer blocks.

(4) Assuming a coefficient of friction of 0.5 or better can be maintained by rolls driving on the surface of a rounded veneer block, this auxiliary drive should deliver about one-half of the torque needed for cutting veneer. More research is needed to establish the feasibility of this concept.

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KEYWORDS: Lathe settings, block temperatures, cutting force, spurs, chucks, block diameter, split out, power, density.

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